RESEARCH DEPARTMENT

A V.H.F./U.H.F. Field-Strength Recording Receiver

Report No. G-056

1955/13

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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SUMMARY

The report describes a pre-tuned receiver for radio-frequency field-strength recording. It has been designed specifically for use in connexion with propagation tests in Band III (174-216 Mc/s), Band IV (470-585 Mc/s) and Band V (610-960 Mc/s), and incorporates a signal-frequency unit for each band and an intermediate-frequency amplifier working at 10·7 Mc/s.

The main characteristics of the receiver are high sensitivity and stability of calibration. The latter feature is particularly important as the recording is required to remain accurate to within ±1 dB for periods of one month, without attention, in spite of normal changes in valves, supply voltage and temperature. The specification and general design of the receiver are discussed, and performance details are given.

1. INTRODUCTION.

The receiver described was designed for recording field strength in the frequency bands allocated for television broadcasting in the United Kingdom, namely Band III (174-216 Mc/s), Band IV (470-585 Mc/s) and Band V (610-960 Mc/s). Several of these receivers are to be used for obtaining information on propagation conditions over long distances. Since only relatively low-power transmitters were available for these tests it was necessary to make the receiver sufficiently sensitive. To achieve a high output signal/noise ratio it was decided, at the outset, to modulate the transmissions at an audio frequency and take advantage of post-detector filtering, while at the same time making provision for recording the field strength of other signals which might not be modulated in this manner.

The investigation of propagation conditions requires accurate and continuous records of field strength for long periods at sites where it may not be convenient for skilled engineers to inspect apparatus more frequently than once a month. The reliability and gain stability of a receiver for this purpose must therefore be high, so that valuable recording time is not wasted either through obvious failure or unsuspected errors.

The following specification was eventually evolved.

2. SPECIFICATION.

The receiver must be able to record the field strength of special transmissions on any frequency in the ranges 174–216 Mc/s and 470–960 Mc/s. These transmissions will be square-wave modulated to a depth of 100% at 1000 c/s ± 1 c/s and the carrier frequency controlled to within 0·01% of the nominal frequency. Continuous tuning is not necessary and the signal-frequency circuits of the receiver may be fixed before installation.

For normal operation, the output of the receiver shall be proportional to the logarithm of the input signal, but facilities shall be provided for a linear relationship if required. The recording error, referred to the input, shall be less than ± 1 dB during a period of up to one month after inspection and calibration, provided that the supply voltage remains within the range 190–250 V r.m.s. The useful gain shall be limited only by fluctuation noise and the noise factor be as low as is reasonably possible, with a maximum of 15 dB. Provision shall also be made for recording the field strength of unmodulated transmissions.

3. DISCUSSION OF SPECIFICATION.

In general, a receiver can be no more reliable than its least reliable component, and the designer, while choosing the best component for a particular purpose, must be aware of its limitations and ensure that its reliability is not impaired by the conditions in which it operates. Certain changes in the values of components must however be tolerated; these arise both from ageing and from changes in supply voltage and temperature. The effect of these changes can often be minimised by care and ingenuity of design. Negative feedback, for example, can provide a high degree of gain stability in some parts of the receiver, so permitting a greater variation in those parts which cannot conveniently be stabilised in this way.

The effect of frequency drift can be overcome by ensuring that the gain of the receiver is constant over a range of frequencies equal to the sum of the maximum drifts expected at the transmitter and the receiver.

To obtain a logarithmic amplitude characteristic, the receiver gain must vary as a function of the input signal. This may be achieved by using one stage of variable gain, but negative feedback cannot then be used to protect the stage from the changes mentioned above. There are also difficulties in applying negative feedback to the signal frequency and mixer stages. Hence, though the effect of supply voltage changes can be minimised by a voltage stabiliser, some gain changes due to ageing and temperature may remain unless suitable precautions are taken.

4. BRIEF OUTLINE OF RECEIVER DESIGN.

In order to obtain the specified performance, a superheterodyne receiver was designed having three interchangeable signal-frequency (s.f.) units and a main unit containing the intermediate-frequency (i.f.) amplifier, detector and post-detector circuits, negative feedback being used wherever convenient. The main unit determines the bandwidth of the receiver, the gain being sensibly constant over a range of ±200 kc/s to accommodate the maximum frequency drift of 0·01% at both transmitter and receiver at the maximum frequency of 960 Mc/s.

An intermediate frequency of 10·7 Mc/s was selected after consideration of the following points. A higher frequency would have simplified image rejection but would also have increased difficulties in development, particularly in obtaining the desired degree of negative feedback. While no special techniques are necessary to obtain the required coil Q-factor of 100 at about 10 Mc/s, a higher frequency would demand higher values of Q for the same bandwidth, and consequently greater stability with temperature. The actual frequency of 10·7 Mc/s, rather than any other in this region, was chosen in the hope that it might eventually become cleared of transmissions, as it is a popular intermediate frequency for v.h.f. broadcast receivers in both Europe and America.

The i.f. amplification is provided by three cascaded three-valve amplifiers, the gain of the second being controlled by a direct voltage derived either from a manual control, or from the output of the receiver; in the latter case a close approximation to the required logarithmic law is achieved. These amplifiers are separated by band-pass filters giving a frequency response constant to within ±0·2 dB over the range ±200 kc/s and falling rapidly outside this range.

The output of either of two separate amplifiers can be selected by a switch to provide post-detector amplification, the choice depending on the type of transmission to be recorded.

For the special test transmissions mentioned earlier, the recorded output is taken from an audio frequency (a.f.) amplifier and detector. This amplifier is preceded by an a.f. filter having an energy bandwidth of about 30 c/s at the modulation frequency of 1000 c/s, resulting in an improved output signal/noise ratio when receiving the special transmissions. For other signals, such as C.W. or programme, the output is taken from a d.c. amplifier, the mean signal level being recorded with negligible error. The receiver is not suitable for receiving transmissions with pulse modulation or steady sinusoidal modulation to a depth greater than 50%, though it can be adapted to record signals which are 100% square wave modulated at frequencies other than 1000 c/s by changing the a.f. filter. Either of the two amplifiers mentioned above can supply an output of 0–1mA d.c. to a recorder having an impedance of 3000 ohms.

A conventional d.c. power unit provides stabilised anode, screen and bias voltages; the r.m.s. mains voltage supplied to the whole receiver is stabilised to within ±1% by a special unit designed for this purpose.

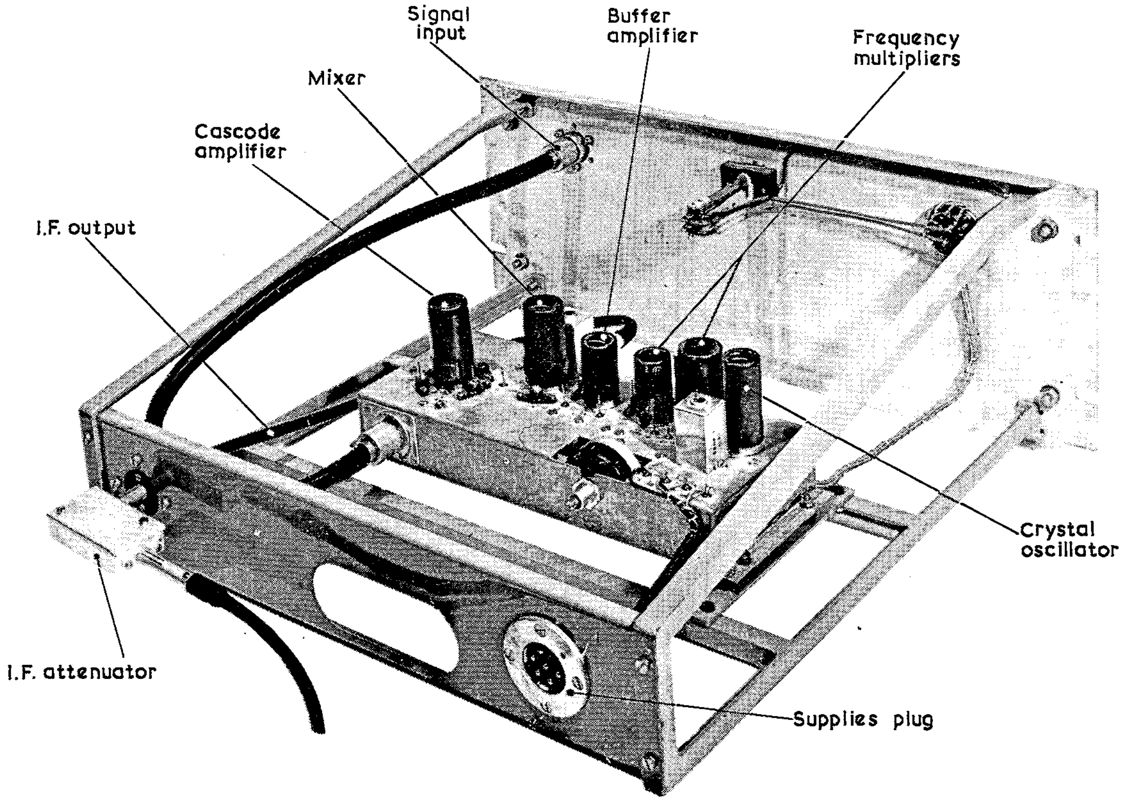

Fig. 1 - Band III signal-frequency unit

5. SIGNAL-FREQUENCY UNITS.

5.1. Band III s.f. unit (174-216 Mc/s).

A photograph of the unit is shown in Fig. 1. The circuit diagram, Fig. 2, shows a double triode type 12AT7 as a cascode s.f. amplifier connected, by a transitionally-coupled pair of tuned circuits, to one section of a second 12AT7 operating as a triode mixer. Coils of silver wire are used for the s.f. circuits, which are tuned by slugs of iron dust or silver-plated copper. The nominal input impedance is 75 ohms and the voltage standing-wave ratio is better than 0·9; the

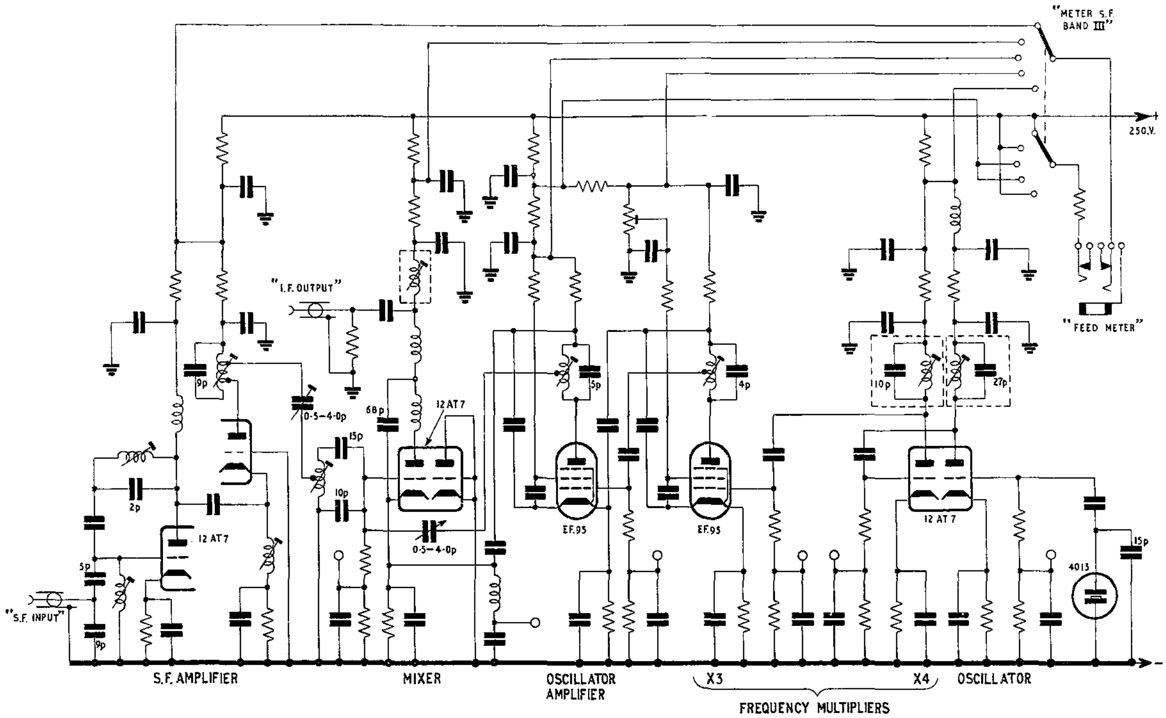

Fig. 2 - Band III signal-frequency unit

output impedance at 10·7 Mc/s is 470 ohms. Provision is made for inserting attenuators between the s.f. and i.f. units if required.

The local oscillator section of the unit comprises a 12AT7 crystal-controlled oscillator and quadrupler, a pentode type EF95 used as a trebler and a second EF95 buffer amplifier, its output being coupled to the grid of the mixer by a variable capacitance. The tuning range of the oscillator and multipliers is sufficient to allow the final frequency to be set either above or below that of the signal; this facility may be required to avoid interference resulting from spurious responses.

5.2. Band IV s.f. unit (470–585 Mc/s).

The unit comprises a tuned input circuit followed by a crystal mixer, and a local oscillator. The mechanical arrangement may be seen from Fig. 3; there are two

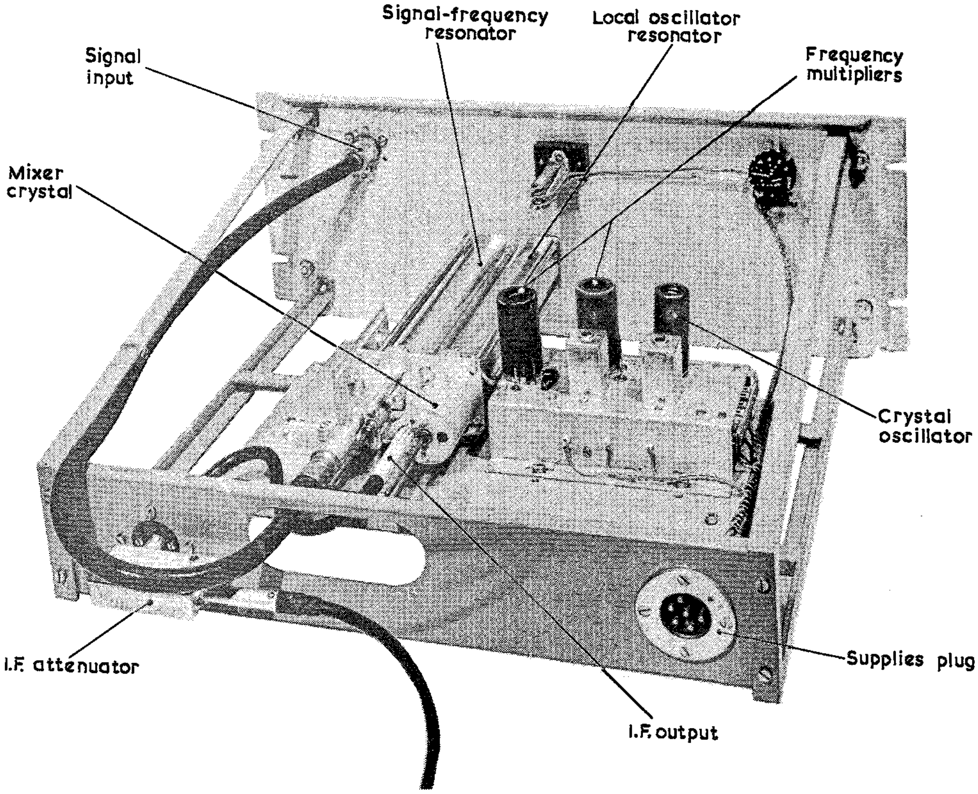

Fig. 3 - Band IV signal-frequency unit

concentric-line resonators and a small chassis containing the crystal oscillator and multiplier stages. The circuit diagram is shown in Fig. 4.

The aerial input is loop-coupled to the first concentric-line resonator which is tuned to the signal frequency. A silicon mixer crystal, mounted at the base of the second resonator, is coupled to the local oscillator and the signal by a loop common to both resonators. The crystal mounting embodies a 100 $\mu\mu$F r.f. bypass condenser which is tuned by a shunt inductance, to resonate at the intermediate frequency; the i.f. output developed across this circuit is fed to the i.f. unit by a short length of 100 ohm cable.

The s.f. resonator has an unloaded Q-factor of about 3000 which is reduced to about 300 by the loading of the source and the mixer, giving a s.f. response which does not materially affect the overall response of the receiver. The image rejection is about 28 dB, which is considered adequate in view of the facility of choosing a final oscillator frequency either above or below that of the signal.

The local oscillator section employs two double triodes type 12AT7, the first as a crystal-controlled oscillator and quadrupler, and the second as two cascaded

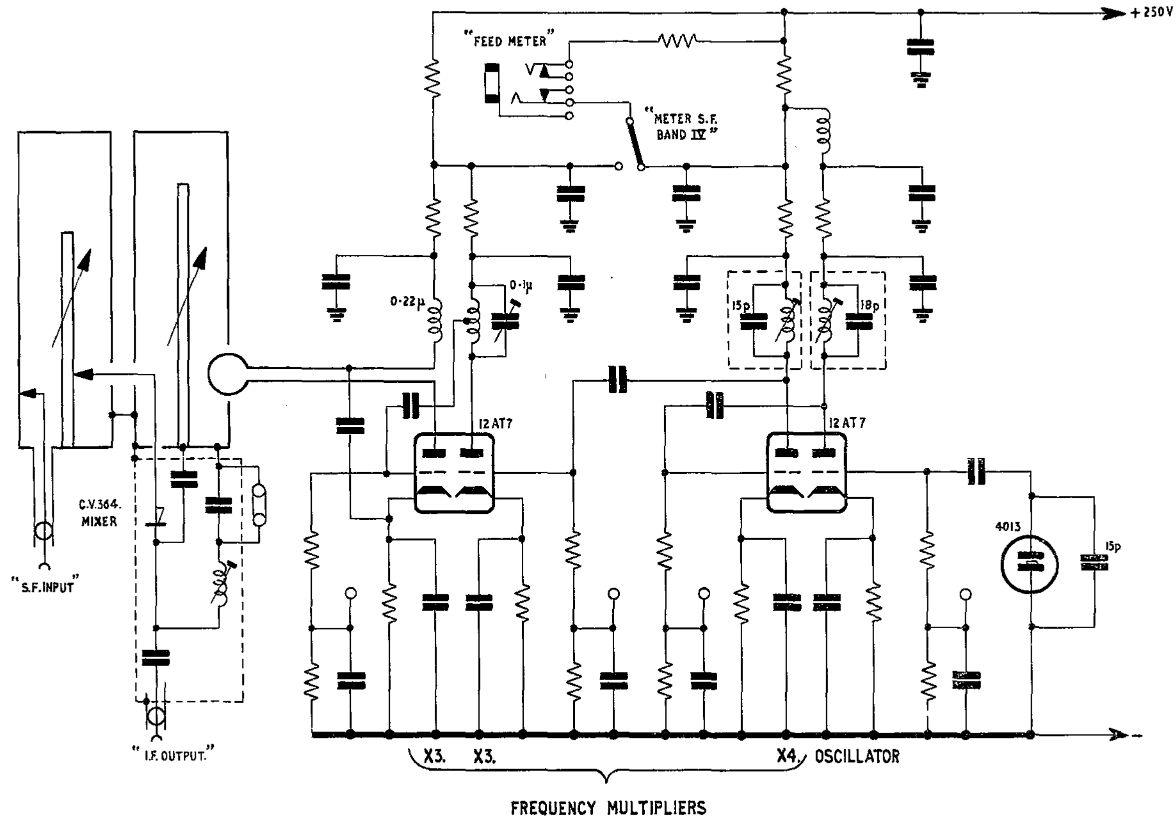

Fig. 4 - Band IV signal-frequency unit

treblers, the final output being coupled by a loop into the second concentric line, resonant at a frequency 36 times that of the crystal oscillator. The high Q-factor of this resonator affords adequate rejection of other harmonics of the crystal oscillator, and so helps to reduce interference resulting from spurious responses.

Each resonator is tuned by a pre-set adjustment of the length of the inner conductor, this being determined by the position of a rod of Nilo 36, an alloy having a low thermal coefficient of expansion.

As in the Band III unit, the input impedance is arranged to be nominally 75 ohms, with an input voltage standing-wave ratio at mid-band of better than 0·9, while the output impedance at 10·7 Mc/s is approximately 470 ohms. Provision is made for the insertion of attenuators between the s.f. and i.f. units if required.

5.3. Band V s.f. unit (610-960 Mc/s).

This unit is still being developed and when completed will be described in an addendum to this report.

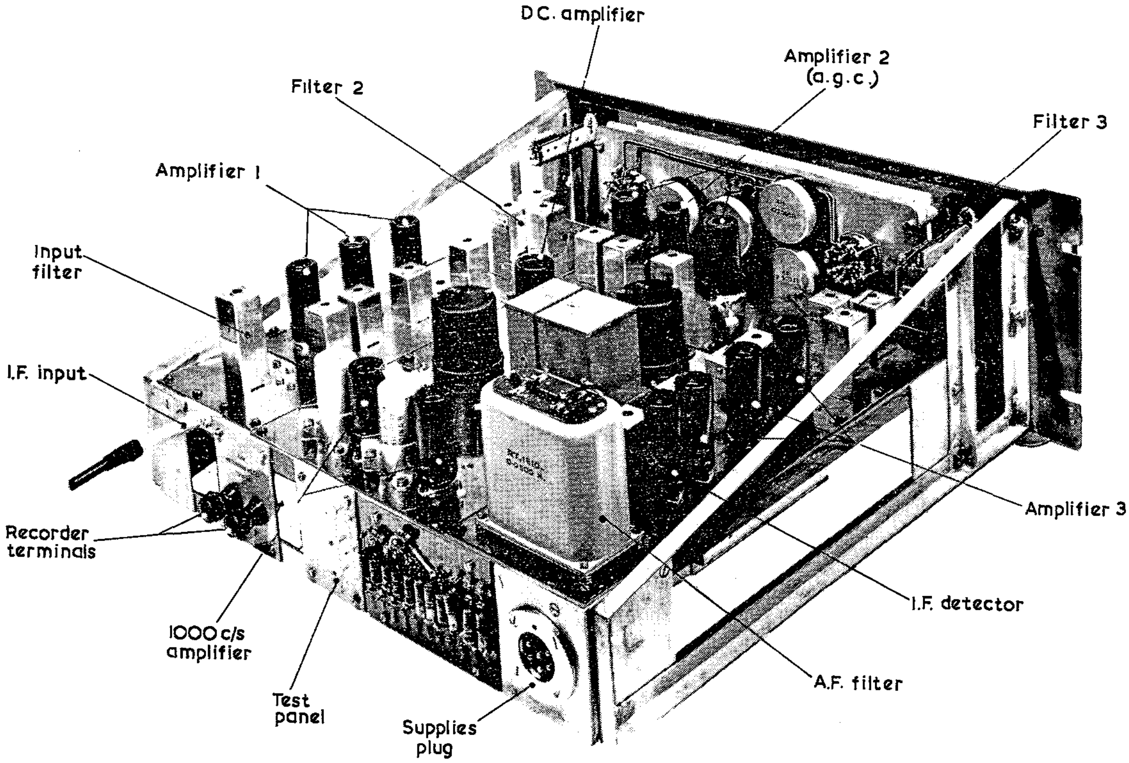

Fig. 5 - Intermediate-frequency unit

6. INTERMEDIATE-FREQUENCY UNIT.

Each of the i.f. amplifiers and filters is built on a separate chassis; these are arranged in cascade on an insulating frame with the post-detector circuits in the centre, as shown in the photograph, Fig. 5. The circuit diagram is shown in Fig. 6.

6.1. Input circuit and i.f. amplifier No. 1.

The input transformer has a Q-ratio of 16 and a transitional coupling-coefficient of 0·1, giving a bandwidth of about 1 Mc/s at −3 dB, and a level response in the pass-band of the receiver. The impedance presented by this circuit to the first amplifier is about 10 000 ohms.

The amplifier incorporates three cascaded pentodes type Z77 with overall negative feedback, the feedback voltage is derived from the cathode circuit of the third valve and applied, through a phase-correcting circuit, to the cathode of the first valve. As this valve is fed from a high source impedance, the input impedance of the valve itself must be made high to avoid loss of feedback; this necessitates tuning out the grid-cathode capacitance by means of an inductance. The reduction in

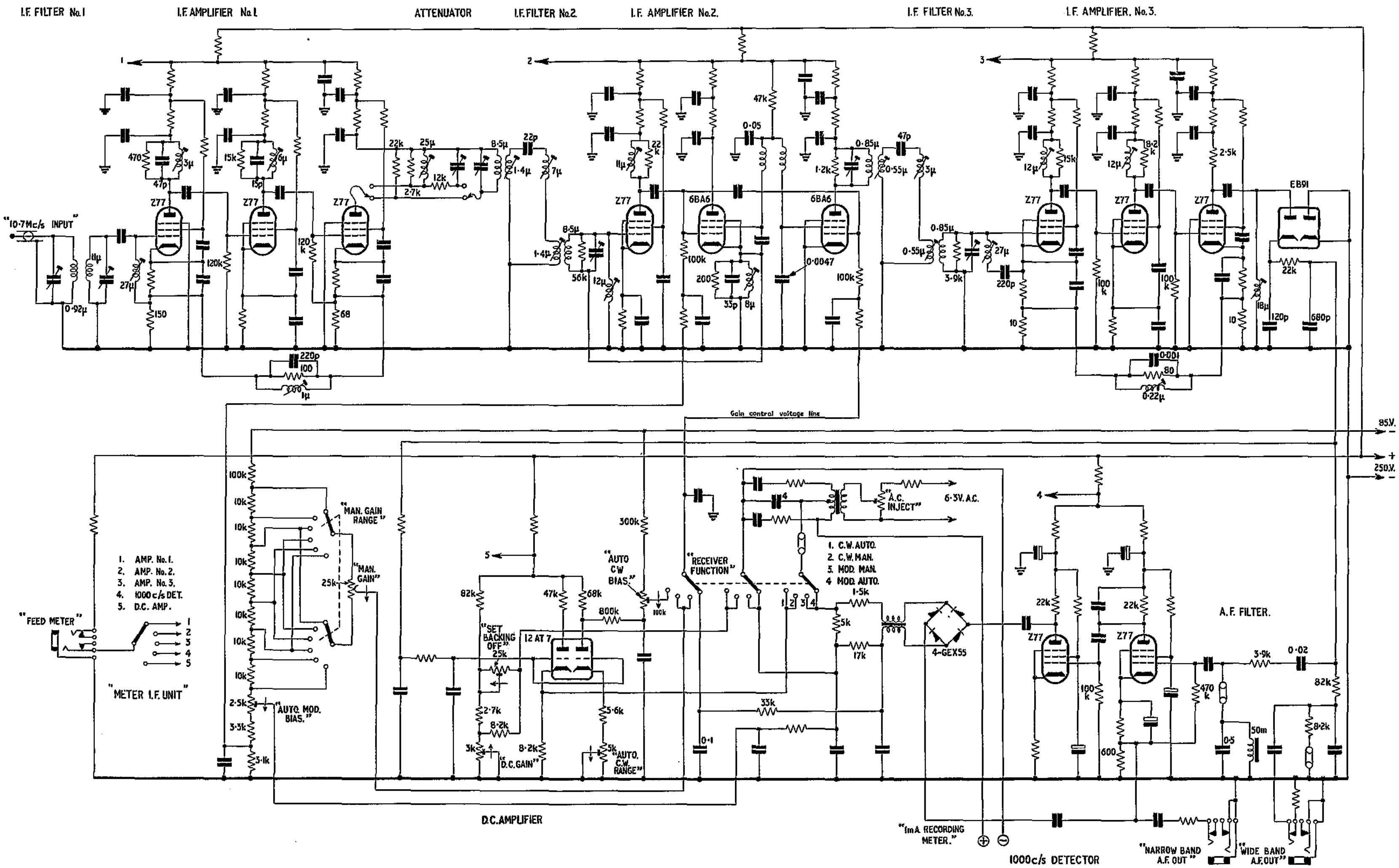

Fig. 6 - Intermediate frequency unit

the gain of the amplifier due to the application of feedback is 32 dB at the intermediate frequency, and the resultant gain can be expressed as a transfer conductance of 40 mA/V. Only this transfer conductance is stabilised by the negative feedback loop, which does not include the anode load circuit of the last stage. The components of this circuit, therefore, in addition to those of the feedback loop, must be particularly stable with time and temperature.

The output is delivered to the next band-pass filter, which has an input impedance of 10 000 ohms, either directly or through a built-in attenuator which may be inserted by changing two soldered connections. This attenuator introduces a loss of about 15 dB and is normally inserted only when operating in Band III, in order to compensate for the higher gain of the Band III s.f. unit without impairing the overall noise factor.

6.2. I.F. amplifier No. 2.

This amplifier contains the stage of variable gain required to achieve a logarithmic amplitude characteristic, the valve being a variable-mu pentode type 6BA6. As the use of overall negative feedback would defeat the effect of gain control, this valve is not included in the feedback circuit; instead, a feedback voltage is derived from the output of another 6BA6, in parallel with the controlled valve, but operating at fixed gain. In this way, although any change in the gain of either valve separately will have a direct effect on the overall gain, the system may be made to compensate for any changes that affect both valves simultaneously.

As shown in Fig. 6, the amplifier comprises a pentode type Z77 driving two valves type 6BA6 with their grids in parallel at the intermediate frequency. The first 6BA6 grid is maintained at a pre-set direct voltage, while its cathode circuit provides an i.f. feedback voltage which is applied to the Z77 grid through the input circuit, the reduction in gain due to feedback being about 28 dB. The grid voltage of the second 6BA6 is derived either from the rectified output of the receiver, as an a.g.c. voltage, or from a manually operated potential divider; this valve forms part of the main amplifier chain, and its output is developed across an anode load of 1000 ohms, this being the input impedance of the next i.f. filter. The overall voltage gain of the amplifier can be varied between the limits of 1·5 and 0·02.

6.3. I.F. amplifier No. 3 and i.f. detector.

As can be seen from Fig. 6, the circuit arrangement of this amplifier is identical with that of amplifier No. 1, but in this case the amount of feedback applied is 26 dB and the voltage gain is 2500. The final i.f. voltage appears across a 2500 ohm resistor in the anode circuit of the third valve and is then rectified by a diode, the signal passing to the post-detector stages.

6.4. I.F. filters.

The selectivity of the receiver is principally determined by the two filters connected between the i.f. amplifiers, shown in Fig. 6 as Filters Nos. 2 and 3. The filter design is based on a confluent band-pass π-section, using coil Q-factors of about 100; the input and output circuits are coupled to the centre circuit by mutual inductance both to provide d.c. isolation and to allow convenient component values to be used. Since the amplifiers have a relatively high input impedance, it has been possible to improve the filter response by underloading, i.e. terminating the filter

by a resistance higher than the mid-band iterative impedance. The resultant response of each filter is uniform to within ±0·1 dB over the pass-band of ±200 kc/s, centred on 10·7 Mc/s, falls to −10 dB at ±400 kc/s and −21 dB at ±600 kc/s.

Filters Nos. 2 and 3 have mid-band iterative impedances of 10 000 ohms and 1000 ohms respectively; the lower impedance of filter No. 3 is necessary both to minimise break-through across the grid-anode capacitance of the preceding 6BA6, when operating at low gain, and to simplify the application of negative feedback to amplifier No. 3.

6.5. Post-detector stages.

The output from the i.f. detector is separated into its a.f. and d.c. components which are fed to separate amplifiers shown in the lower half of Fig. 6. The switches selecting the operation and output of the receiver are described in Section 8.

6.5.1. 1000 c/s filter, amplifier and detector.

The a.f. component of the rectified i.f. output is first passed through a narrow-band filter, consisting of a resistor in series with a parallel tuned circuit resonant at 1000 c/s, having a bandwidth of ±12 c/s at −3 dB. This filter passes the fundamental component of the modulation on the special test transmissions described in Section 2 and, in so doing, gives an a.f. signal/noise ratio of 0 dB for an i.f. signal/noise ratio of −19 dB. The output is amplified by two Z77 pentodes in cascade and rectified by a bridge circuit using four GEX55 germanium diodes, while the a.f. current through the bridge is returned to the cathode of the first Z77, giving about 28 dB of negative feedback round the whole circuit.

The d.c. load, consisting of three resistors in series, is connected across the bridge output terminals through a bifilar choke, which allows the a.f. current to flow freely between the bridge terminals while presenting a high impedance to current flowing from the bridge to earth. In this way, the load may be connected to earth at any point without disturbing the feedback at 1000 c/s. A negative a.g.c. voltage of 0–30 V is provided by this d.c. load and part of the load current provides the 0–1 mA output for the recording meter.

6.5.2. D.C. amplifier.

The d.c. component of the rectified i.f. output is passed through a low-pass filter to remove any modulation frequencies and applied, as a positive voltage, to both grids of a 12AT7 double triode. One section of this valve supplies 0–1 mA for the recording meter, connected between its cathode and a point at a pre-set positive voltage, while the other section supplies the a.g.c. voltage. The anode voltage of the second section falls as the signal increases, the negative a.g.c. voltage of 0–30 V being obtained from a point on a potential divider connected between its anode and a stabilised negative supply.

6.5.3. A.C. injector.

With the conventional type of 3000 ohm d.c. pen recorder, some of the fine structure of the record is distorted due to static friction, and it is sometimes desirable to improve the response by adding a small alternating current to the recorded direct current. This facility is provided by a bridge circuit using a centre-tapped transformer across the output to the recording meter, as shown in Fig. 6. The

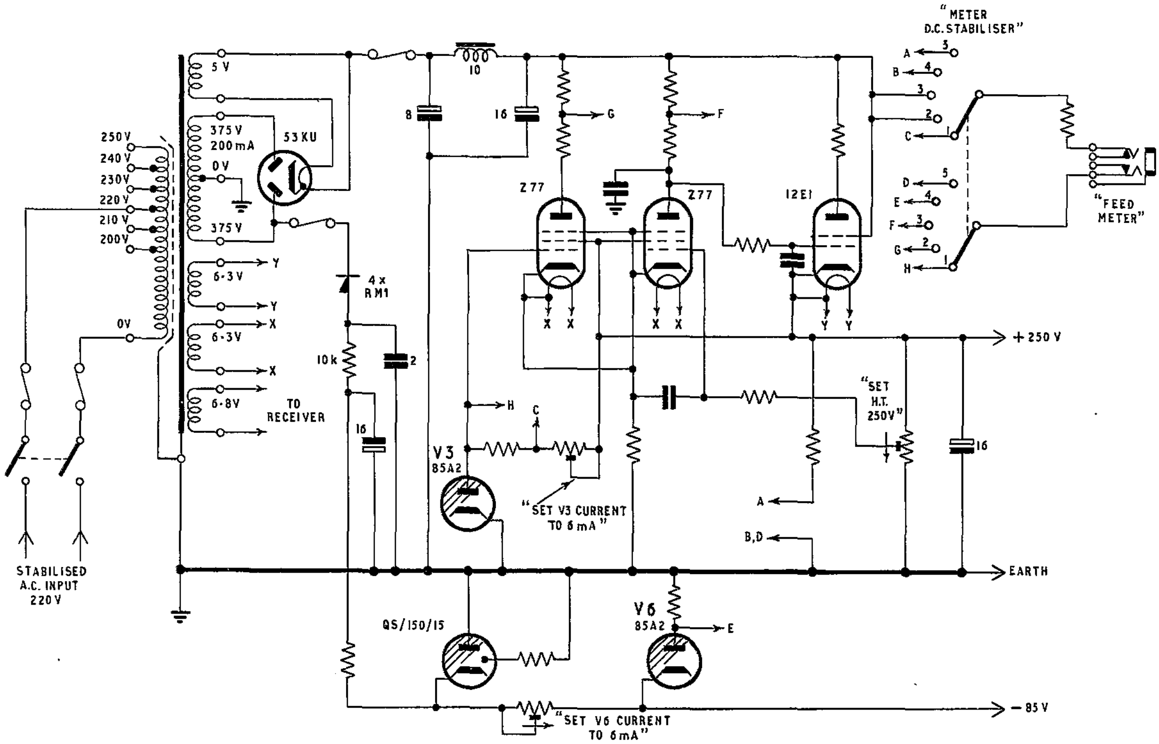

Fig. 7 - Stabilised d.c. power unit

injected current can be varied up to a maximum of 0·1 mA r.m.s. for this type of recorder, at the supply frequency of 50 c/s. The bridge is balanced by a dummy load so that the a.c. is not fed back into the d.c. source.

7. POWER SUPPLIES.

7.1. Stabilised d.c. power unit.

The circuit (shown in Fig. 7) is that of a conventional stabilised d.c. power supply using a full-wave rectifier followed by a condenser input filter and a series regulator valve. The impedance of the series valve is controlled by a two-stage d.c. amplifier to compensate for changes in the output voltage, the voltage reference being provided by a neon stabiliser type 85A2.

The unit will give a constant 250 V output at up to 150 mA for all input voltages from 190-250 V r.m.s. In addition, a metal rectifier and neon stabilisers provide a constant 85 V negative supply for the gain-control circuits of the receiver.

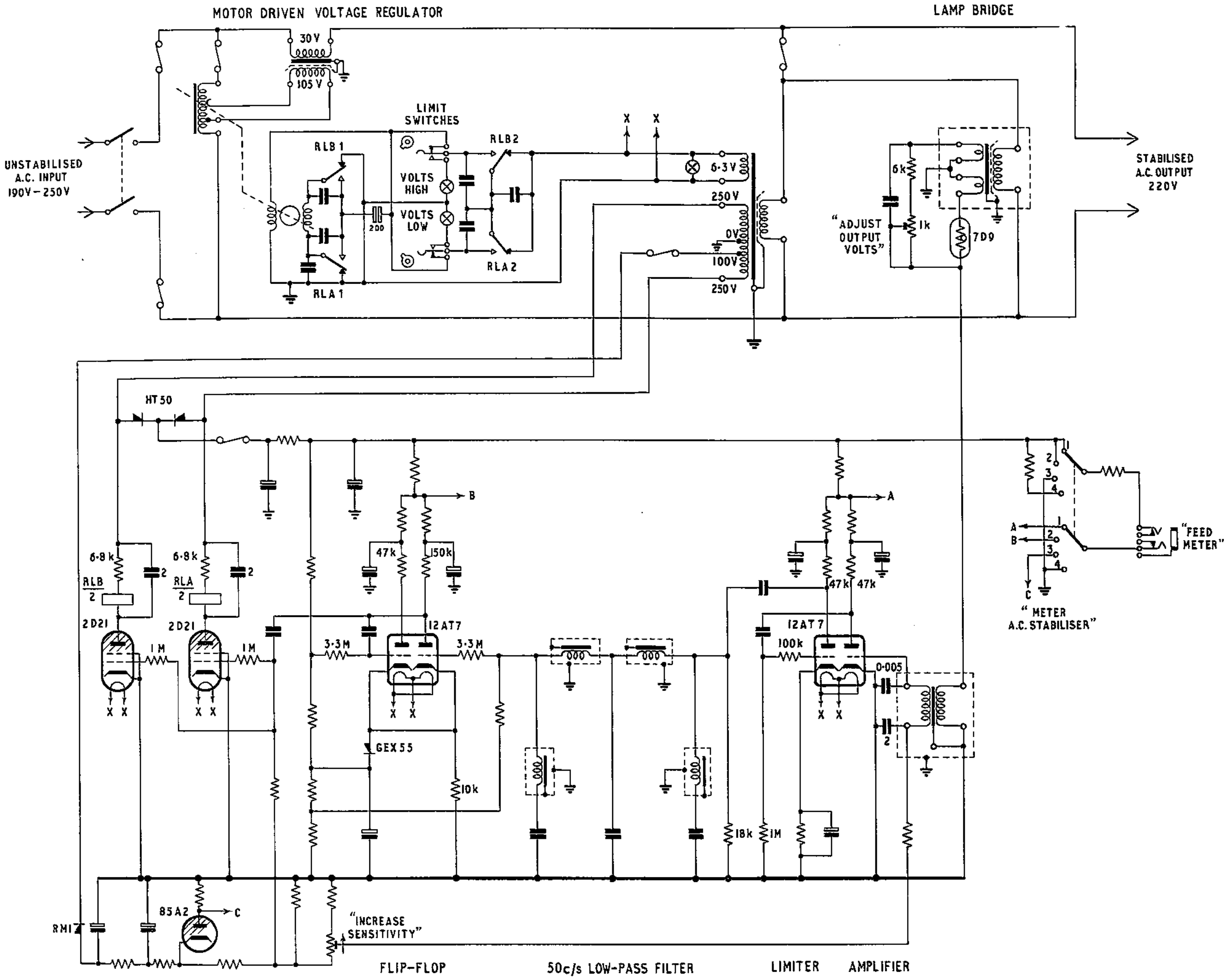

Fig. 8 - A.C. stabiliser

7.2. A.C. stabiliser.

This unit will accept a mains input at any voltage between 190 V and 250 V r.m.s. at any frequency between 40 c/s and 60 c/s. It will deliver an output power of up to 1·7 kW at 220 V r.m.s. ± 1%, the voltage difference of up to ± 30 V being added or subtracted automatically using a "buck-and-boost" transformer.

As shown in Fig. 8, the secondary of this transformer is connected between the live terminals of the input plug and output socket, the neutral terminals being directly connected. The primary winding is supplied from the slider of a variable auto-transformer fed from the input, the slider being adjusted by a small motor until the output returns to 220 V. The rate at which the unit corrects for a change of input is approximately 3 volts per second.

An error voltage is derived from the output of the unit by means of a lamp bridge which is adjusted to balance at 50 c/s when the output voltage is 220 V r.m.s. When the balance is disturbed, a signal proportional to the error voltage is passed through an amplifier, a limiter, a 50 c/s filter and a "flip-flop" circuit, finally arriving as a train of pulses at the grids of two thyratrons, their anodes being fed in antiphase at 50 c/s through two relays controlling the motor. In this way, the sense of the error voltage determines which thyratron conducts and the direction in which the motor adjusts the correcting voltage.

Since it is the r.m.s. value of the output voltage which is stabilised by this unit, the cathode temperature of the valves in the receiver which it supplies will remain sensibly independent of the mains input for a wide range of voltage, frequency and waveform.

8. OPERATION, CONTROLS AND METERING.

It is intended that the receivers be mounted in pairs in steel cabinets approximately 6 ft (2 m) high and 2 ft (0·6 m) square, each receiver consisting of one s.f. unit, one i.f. unit and one d.c. power unit; the two receivers are fed from a common a.c. stabiliser. There is also a panel containing two meters, mounted between the receivers. One of these meters gives a permanent indication of the stabilised supply voltage and the other may be connected by a flying plug lead to any of the units for metering purposes.

The photograph in Fig. 9 shows the arrangement of the units in the cabinet. The principal controls and some of the pre-set adjustments are recessed in the front panels and are normally covered by detachable metal plates. The functions of these controls and other features are described in the following subsections.

A major adjustment of the amplitude and frequency characteristics of the receiver is regarded as a laboratory operation and is not intended to be carried out in the field.

8.1. Signal-frequency units.

The principal controls are all pre-set internally and locked on test. Other internal features include test points for checking the s.f. response and the grid drive of the multipliers.

The anode currents of all valves may be checked during operation using the flexible plug lead and a rotary panel-switch.

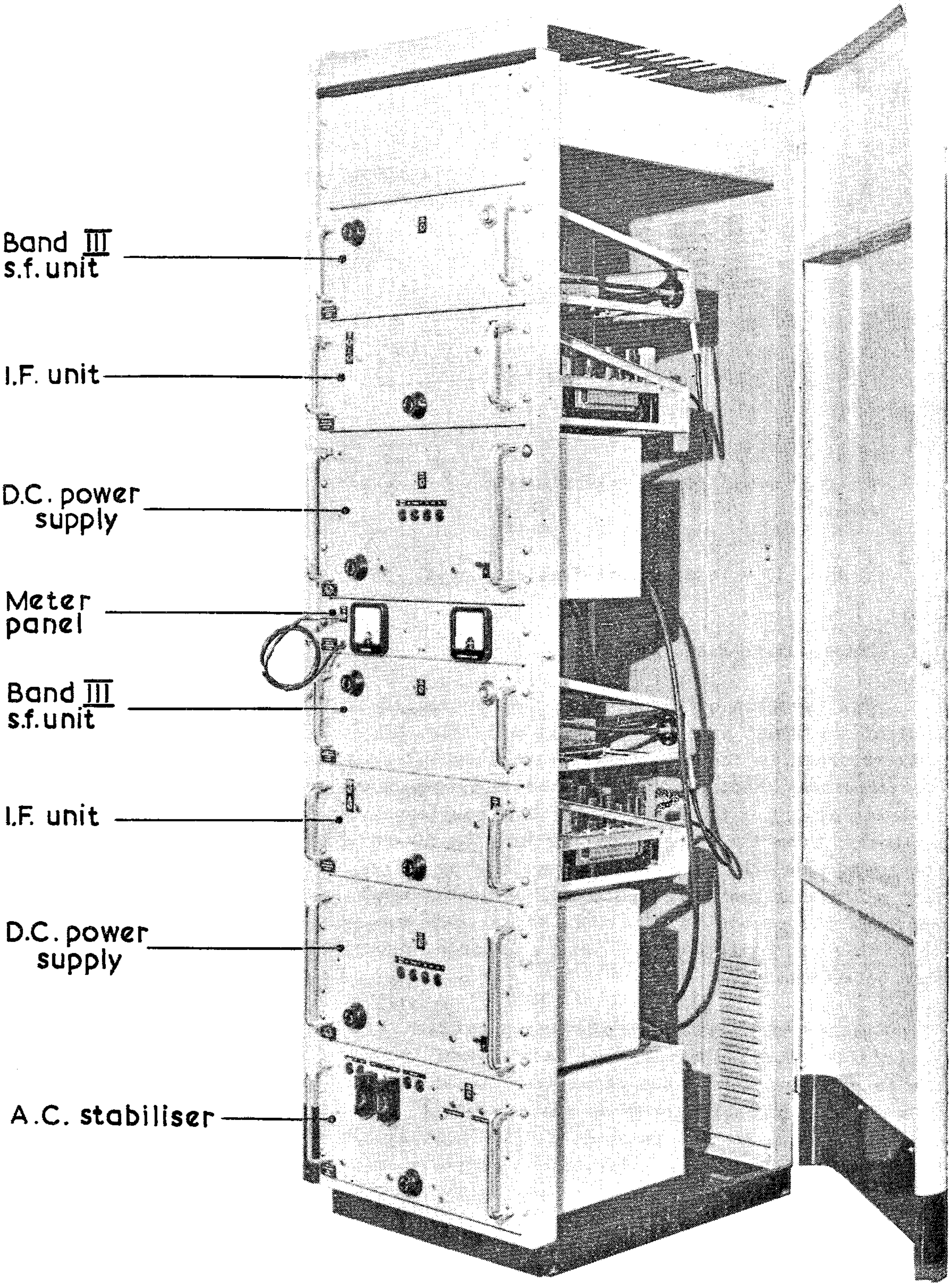

Fig. 9 - Cabinet containing two complete Band III receivers

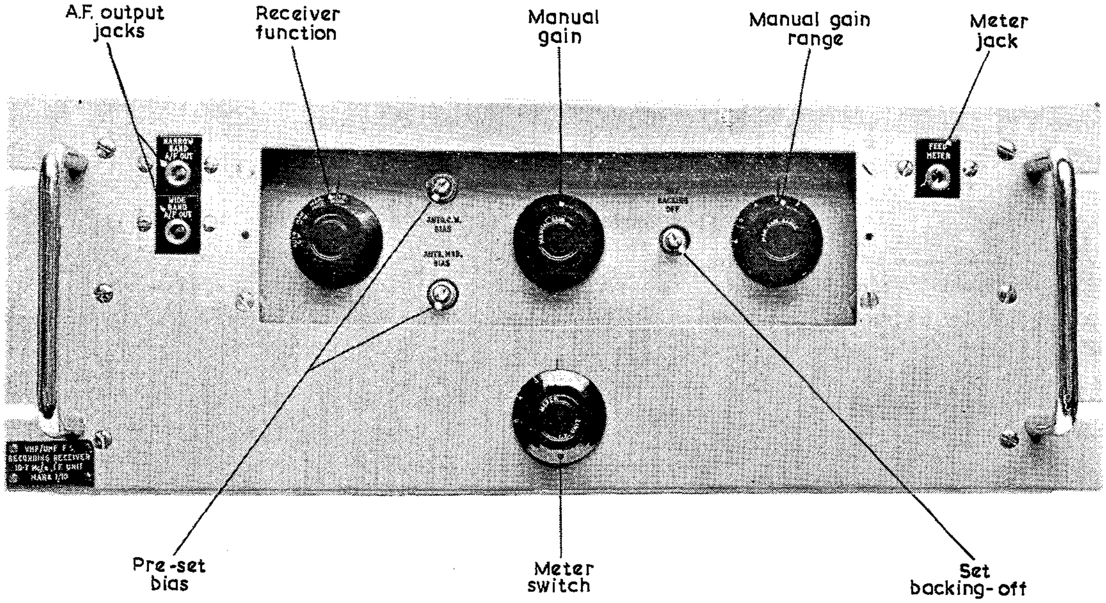

Fig. 10 - Intermediate-frequency unit: front panel controls

8.2. Intermediate-frequency unit.

The function of the receiver is controlled by the four-position switch on the left of the front panel recess, shown in Fig. 10. This determines whether the quantity recorded is the mean carrier level (C.W.) or the modulation of the special test transmissions (Mod.) and whether the amplitude characteristic is linear (Man.) or logarithmic (Auto.). On the C.W. and Mod. positions, the recorder current is taken, respectively, from the d.c. amplifier and the 1000 c/s amplifier, while the gain-control voltage is taken from the appropriate amplifier output on the Auto. positions and from a manually controlled potential divider on the Man. positions. The remaining two knobs in the recess are for this manual gain control, one being a six-position switch giving approximately 6 dB steps in gain, and the other giving a continuous coverage between steps.

Other pre-set controls are provided for adjustment of the amplitude characteristic, a.c. injection and backing-off the recorder current. The latter feature is only operative when recording C.W. since only then is the output current due to noise undesirably large at maximum gain. It is arranged to suppress the recorded noise level to zero on Auto. C.W. without disturbing the input level required for full scale deflection. The 0-1 mA output for a 3000 ohm recording meter is taken from a pair of terminals at the rear of the unit.

Two jacks are provided on the front panel giving high impedance outputs for monitoring the a.f. content of the signal before and after the bandwidth reduction of the a.f. filter. If desired, the filter may be omitted by removing a link, allowing the full bandwidth of the a.f. amplifier to be available for listening to programme; as this disturbs the i.f. detector load, this link should not be removed while

recording the mean level of a modulated signal. The types of modulated signal for which the receiver is suitable have been mentioned in Section 4.

A five-position meter switch enables the total current of each of the amplifiers to be checked during operation.

8.3. Power supplies.

The d.c. power unit front panel recess contains adjustments for the stabilised output voltage and the neon stabiliser currents, which may be measured by the metering system.

The a.c. stabiliser has a similar metering system, and pre-set adjustments for the stabilised output voltage and the sensitivity of the correcting circuits.

9. RESULTS OF PERFORMANCE TESTS.

9.1. Selectivity.

The frequency response of a typical i.f. unit is shown in Fig. 11(a), while the response of the individual Band III and Band IV units is shown by curves b and c respectively. The response does not vary more than ± 0·2 dB over the 400 kc/s pass-band, though a slight change, within these limits, occurs when attenuators are inserted between the s.f. and i.f. units.

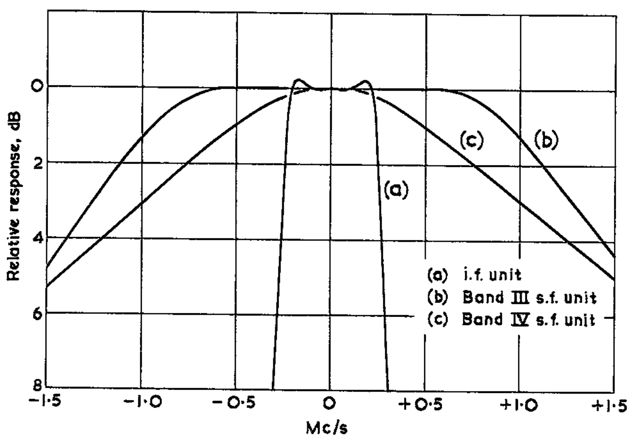

Fig. 11 - Frequency response of i.f. and s.f. units

Tables 1 and 2 give the type and amplitude of spurious responses which occur with the Band III and Band IV receivers. They show the relative amplitude of a signal at the spurious frequency which causes an error of 1 dB in the indicated amplitude of a fixed reference signal in the pass-band. These tests were made with the receiver operating on C.W. at a fixed gain to produce an i.f. detector current of 50 μA with the reference signal alone. No i.f. attenuators were inserted.

TABLE 1

Spurious responses, Band III

Type of response		Input voltage at spurious frequency relative to a 10 μV reference signal at f_o for 1 dB error, dB
$f_b < f_o$*	$f_b > f_o$	
$f_b - f_i$	$f_b + f_i$ (image)	52
$13f_c - f_i$	$11f_c + f_i$	58
$2f_b - f_i$		70
$2f_b + f_i$		60
$3f_b - f_i$		54
$3f_b + f_i$		55
Other responses		> 60

where f_o = signal frequency

f_b = final oscillator frequency

f_c = crystal frequency

f_i = intermediate frequency

*For the above measurements, the final oscillator frequency was below that of the signal. If their relative position were reversed, the first two types of response would be changed, as shown in the Table, with little change in the magnitudes of the responses.

TABLE 2

Spurious responses, Band IV

Type of response		Input voltage at spurious frequency relative to a 30 μV reference signal at f_o for 1 dB error, dB
$f_b < f_o$	$f_b > f_o$**	
$f_b - f_i$	$f_b + f_i$ (image)	20
$37f_c - f_i$	$35f_c + f_i$	58
$37f_c + f_i$	$35f_c - f_i$	65
$56f_c + f_i$		59
$56f_c - f_i$		61
$60f_c + f_i$		57
$60f_c - f_i$		56
f_i (i.f. break-through)		60
Other responses		> 60

where f_o = signal frequency

f_b = final oscillator frequency

f_c = crystal frequency

f_i = intermediate frequency

**For the above measurements, the final oscillator frequency was above that of the signal. If their relative position were reversed, the first three types of response would be changed, as shown in the Table, with little change in the magnitudes of the responses.

9.2. Sensitivity.

The noise factors of the receivers are given in Table 3, with figures relating to the limiting sensitivity. The i.f. unit noise factor was 3·2 dB.

TABLE 3

Band	Noise factor, dB	S.F. unit gain dB	Internal attenuator loss, dB	R.M.S. signal input μV for			
				Unity output signal/noise ratio		0·01 mA meter deflection	
				C.W.	Mod.	Auto C.W.	Auto Mod.
III	7	+15	15	1·1	0·13	0·75	0·18
IV	13	−10	0	3·5	0·4	3·5	0·8

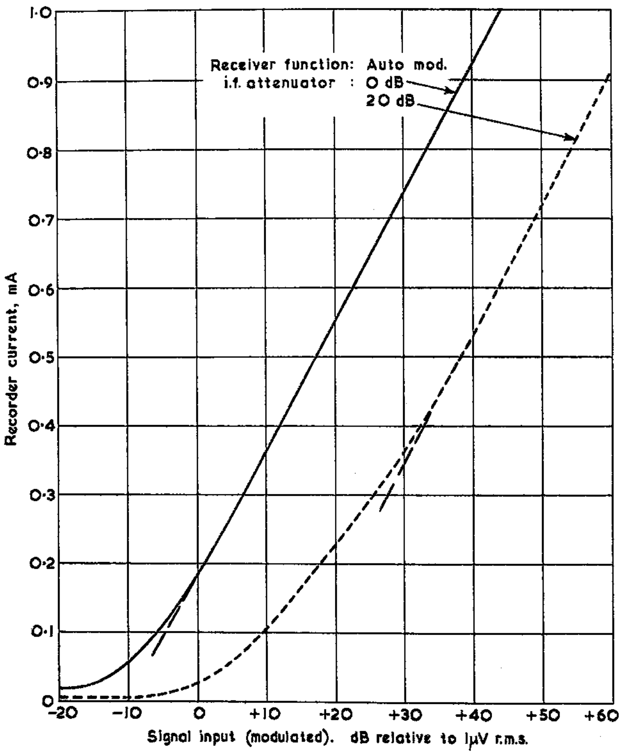

Fig. 12 - Calibration curve for a typical Band III receiver

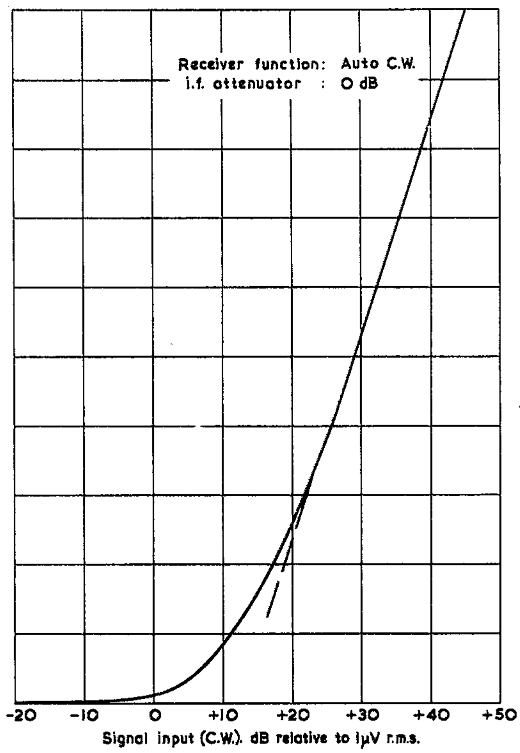

Fig. 13 - Calibration curve for a typical Band III receiver

Figs. 12 and 13 show typical calibration curves for a Band III receiver operating on Auto Mod. and Auto C.W. respectively. The relationship on Auto Mod. is a good approximation to a logarithmic law over most of the recording range, which extends for 60 dB above the input level required for a unity signal/noise ratio output; the law is similar for the Band IV receiver. As shown by the dotted curve, however, there is a change in the characteristic when an attenuator is placed between the s.f. and i.f. units. This condition exists when, with no attenuator, the recorded output is less than 30% of full scale; the signal/noise ratio at the i.f. detector is then

less than unity and that part of the detector output selected by the a.f. filter is dependent on the i.f. noise level.

When recording a modulated signal with the receiver set to Auto C.W., the amplitude characteristic remains unchanged for constant modulation depths less than 50%. With programme modulation, and the receiver gain set to give an output of 1 mA, modulation peaks were severely distorted in the a.f. output, but the effect on the recorded level was negligible.

9.3. Stability.

Six complete Band III receivers, three recording the output of each of two signal generators, were run continuously for a period of 4 weeks; two of these receivers were run continuously for an additional ten weeks and intermittently for two weeks. No significant relative change in the output of the receivers in each group was observed, provided the signal generator frequency remained in the pass-band. Any drift in their absolute output could be attributed to the effect on the signal generator of fluctuating temperature and mains voltage.

A similar test on the Band IV receiver has not yet been performed, but all the units have been tested in an oven over the temperature range 20°C to 50°C; the changes observed in the resonant frequency of tuned circuits and in the gain of each unit were such as to produce a maximum change well within the specified limit of ±1 dB.

The time required, after switching on, before the receiver has reached its final calibration, is approximately 5 minutes.

9.4. Co-channel interference rejection.

When receiving the modulated test transmission with the receiver switched to Auto Mod., the gain of the receiver is controlled by the amplitude of the modulation, so that if a signal not modulated at 1000 c/s is present in the pass-band, there will be no appreciable change in gain or output until the amplitude of this unwanted signal approaches the overload level in the i.f. amplifier. When overload occurs, the wanted signal output will suddenly decrease and the gain will increase, thus enhancing the effect and causing paralysis. This overload level for a typical receiver is shown in Fig. 14 curve (a). If the

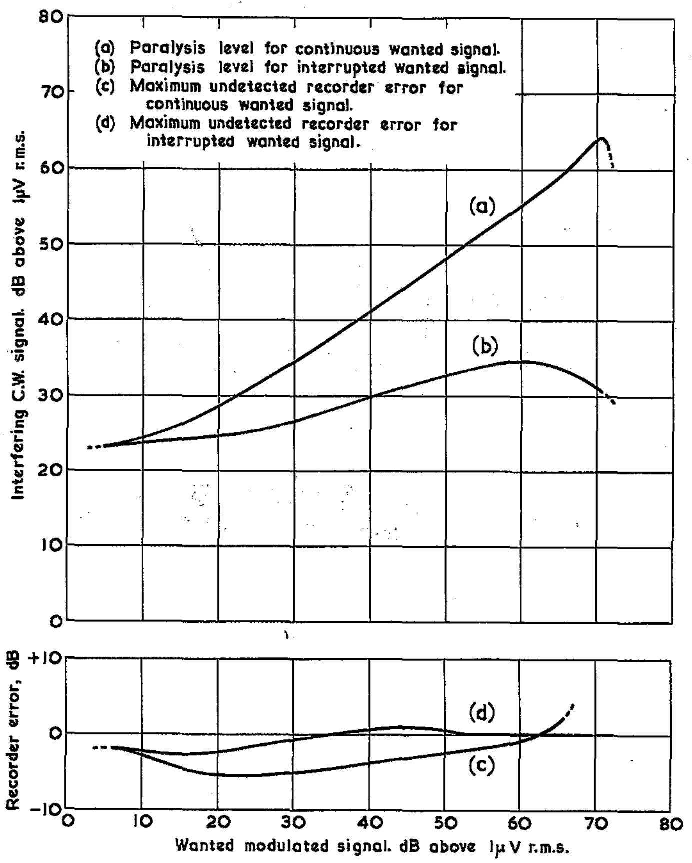

Fig. 14 - Co-channel interference characteristic

unwanted signal is then reduced in amplitude, paralysis will continue to occur until curve (b) is reached, when the modulation reaching the a.f. detector will be sufficient to take control of the receiver gain. The recording error at these levels is shown on the same figure in curves (c) and (d).

Thus, if an interfering C.W. signal is present in the pass-band while recording a steady, modulated test transmission, the maximum undetected error will be given by curve (c), since it will be clear from the record if overload has occurred by the sharp and sustained fall in output. If, on the other hand, the test transmission is broken at regular intervals for identification marks, the error becomes obvious at a lower value, given by curve (d) since, if the interference is greater than (b) paralysis will occur at the next break in the test transmission and continue until the interfering signal falls below curve (b).

The curves in Fig. 14 refer to a C.W. signal differing in frequency from the wanted signal by 50 kc/s or greater, and will be modified if the frequency difference falls below this value, or if the interference contains modulation at 1000 c/s.

10. THE DESIGN OF FUTURE RECEIVERS.

In view of the satisfactory performance of this receiver to date, the i.f. unit may become the basis for the design of other receivers, with signal-frequency units designed for other bands. This would ease the problems of maintenance and training in operational service. If a special application requires a different i.f. bandwidth, it would be a simple matter to replace the existing i.f. filters by others having bandwidths ranging from ±50 kc/s to ±1 Mc/s.

11. CONCLUSIONS.

The results of tests show that the performance of the receiver meets the specification for stability, amplitude characteristic and noise factor in Bands III and IV. It is expected that, when the development of the Band V signal-frequency unit is complete, its performance will be similar. Apart from meeting the requirement for noise factor, an improvement in the effective signal/noise ratio has been obtained by the use of a modulated test transmission and post-detector selectivity.

It is suggested that the receiver might become the basis for the design of receivers for other bands, by the use of other signal-frequency units.

12. ACKNOWLEDGMENTS.

Advice on the theoretical design was given by C.G. Mayo. The preliminary work on the i.f. amplifiers was carried out by D.J. Whythe. The lining-up and testing of the equipment was carried out with the assistance of R.J.H. Slaughter and P. Gill. R.G. Dilley assisted in the construction of the prototype receiver.